DISTURBED SOIL SIGNATURES FOR MINE DETECTION

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ABSTRACT

We are investigating the phenomenology of disturbed soil signature due to mine emplacement. Non-imaging spectral sensors and high-frequency radars are being used to collect disturbed soil signatures over a wide range of geo-environmental conditions. The properties and processes of the disturbed soil that can be exploited to assist in the detection of buried landmines are first identified. This will be followed by time series investigation to understand the effects of weathering on these properties and processes. Our goal is to provide a quantitative assessment of remote electro-optical and radar techniques for reliably detecting disturbed soil due to mine emplacement.

1. INTRODUCTION

Detecting buried landmines is made difficult by their diverse sizes, shapes, composition, and burial depths. The problem is further complicated by the diverse environmental conditions in which these mines are likely to be encountered. Recent mine-detection technologies (for example, elector-optical/infrared, surface penetrating radar, seismic/acoustic and trace chemical detection) have made significant advances in detection capability. However, these technologies still cannot meet the operational requirements imposed by the Army. Innovative research that couples the physics of landmine detection technology to landmine signature changes impacted by soil and weather conditions are needed in order to improve current mine detection capability.

Creating a minefield requires disturbing the soil. This disturbance alters the soil properties and processes, which are measurable. Anecdotal evidence and measurements suggest that the altered properties of disturbed soil above a buried landmine may persist for months. Identifying localized areas of soil that have been disturbed amidst the undisturbed soil may be a first step in detecting buried landmines.

The US Army is currently investigating hyperspectral and radar techniques to exploit the altered properties disturbed soil to assist in the detection of buried landmines. Numerous studies have been conducted to understand the spectral signatures of the soil disturbed during mine emplacement and the surrounding undisturbed soil (DePersia et al., 1995; Winter et al., 1996; Schwartz et al., 1999; Haskett et al., 2000). The focus of our research is on the detection of residual surface disturbances caused by mine emplacement using VNIR and LWIR sensors coupled with high-frequency radar. We have initiated ground-based measurements using non-imaging spectral and radar sensors to investigate the phenomenology of disturbed soil signature at several government test facilities. We present some preliminary results of our investigations. The goal of our investigations is to identify optimal strategy for exploiting the properties and processes of the disturbed soil to assist in the detection of buried landmines.

2. FIELD MEASUREMENTS

Soil spectral signatures at UV/VNIR regions were investigated using Analytical Spectral Device field spectrometer. A sample spectral plot obtained from disturbed and undisturbed sections of a mine test lane is illustrated in Figure 1. This test bed was prepared on a crushed gravel road. The gravel road was virtually free of traffic so that small amount of vegetation had taken hold. During mine emplacement the surface vegetation was removed and replaced with subsurface soil. A notable feature in this plot is the reflectance dip observed around 0.65 um in the undisturbed section of the test bed. The figure illustrates that even a small amount of vegetation can affect the soil spectra around 0.65 μm. This region of the spectrum corresponds to the maximum absorption peak of chlorophyll.

Soil spectral signatures at the LWIR regions were collected using Design and Prototypes field portable Fourier transform infrared (FTIR) spectrometer. Figure

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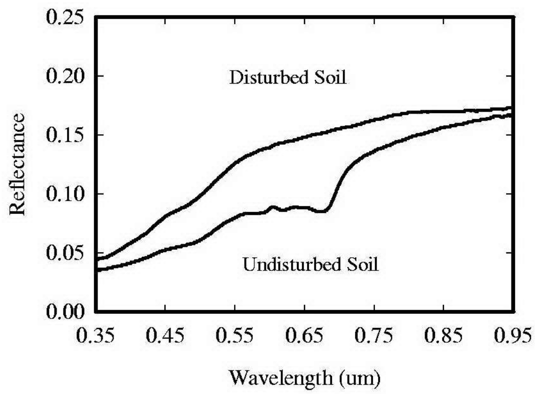

Figure 1. VNIR spectra of disturbed and undisturbed soil measured at a crushed gravel test lane. The plateau observed around 0.65 µm is due to small amount vegetation on the undisturbed portion of the mine test lane.

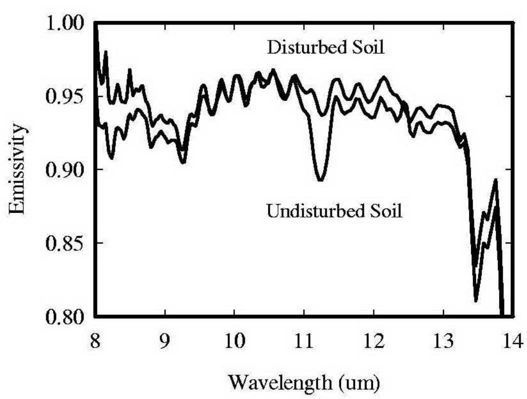

Figure 2. LWIR spectra of disturbed and undisturbed soil measured at a gravel test lane. The emissivity dip observed around 11 µm corresponds to limestone present in the gravel.

2 illustrates FTIR measurements obtained at a limestone gravel test bed. The limestone signature at 11 µm is observed for the undisturbed portion of the site. When the soil is disturbed, the underlying soil is brought to the surface masking the limestone signature. Another LWIR feature of disturbed soil can be exploited to detect buried object is the silicate Reststrahlen feature in the 8.5-9.5 µm window. However, this was not observed at this particular mine test lane.

The radar signature of disturbed soil was collected using a field portable FMCW radar operating at Ku-band. This high-frequency radar responds to the differences in surface roughness of the disturbed and undisturbed soil. Figure 3 illustrates relative radar backscatter intensity from disturbed and undisturbed locations measured at normal incident angle. Higher radar return is observed for the undisturbed portion of

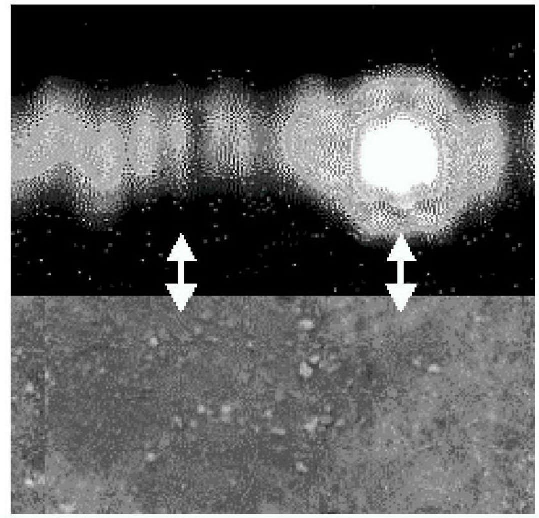

Figure 3. Ku-band radar backscatter measured over a crushed gravel test bed. The disturbed soil (left) results in lower backscatter intensity at normal incident angle.

the soil. Although it is not illustrated in the figure, the reverse is observed when the radar incident angle increases. The crossover angle depends on the relative differences in the roughness between the two locations.

3. SUMMARY

We have observed that spectral and radar signatures are associated with the soil disturbed during mine emplacement. Time series changes in these signatures will be investigated to better understand the phenomenology of disturbed soil signature. The effects of weathering on the disturbed soil signatures are of particular interest. In addition, we will explore the fusion of spectral and radar signatures to identify localized areas of disturbed soil to assist in the detection of buried landmines.

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